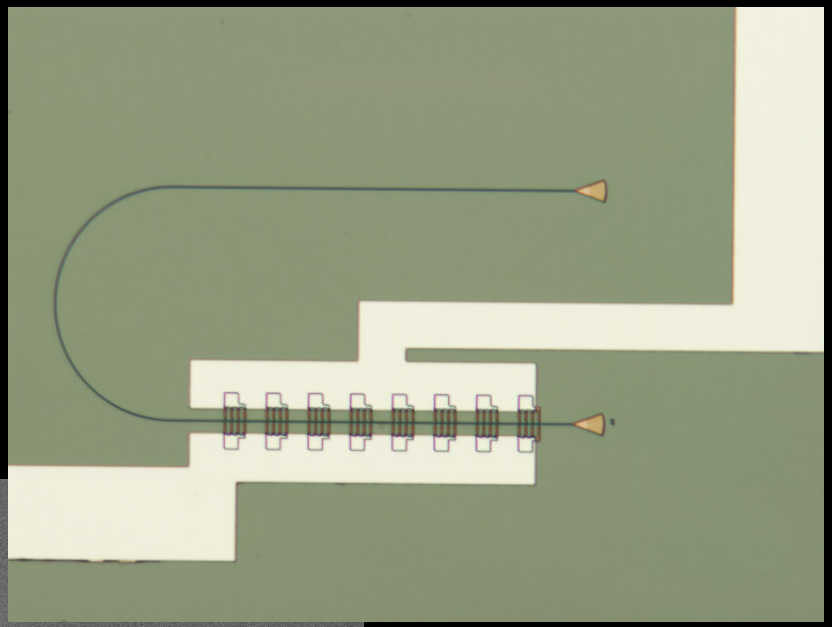
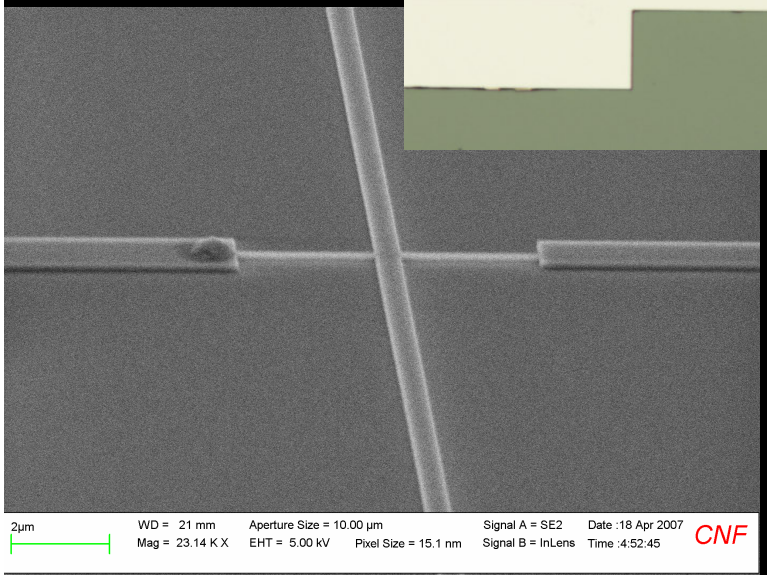
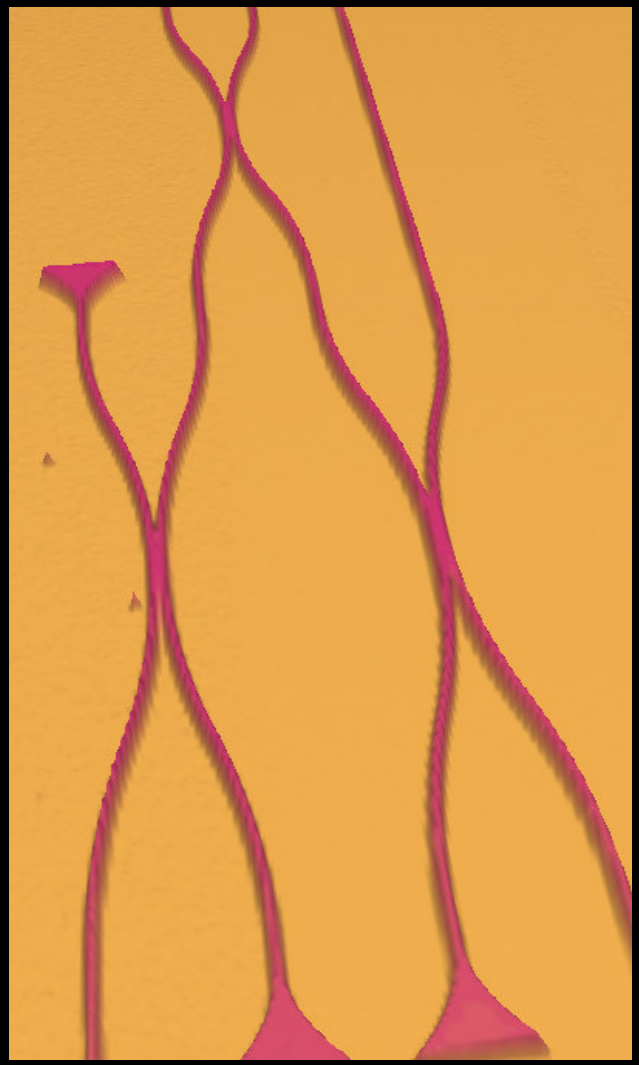
Silicon-Organic Optical Computing

Professor Michael Hochberg





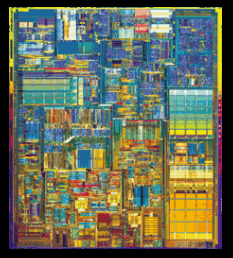


Electronics and Photonics Integration

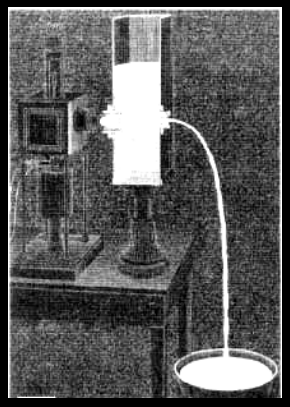
Lightning in a bottle (1750)

Vacuum tube

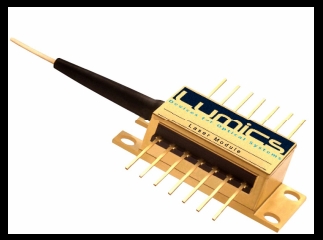
Transistor



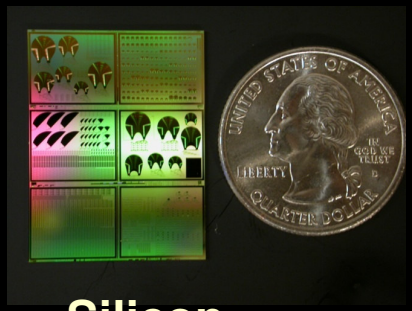
Integrated Circuits (invented 1958)



Guiding light (1841)



Fiber Circuits



Silicon Nanophotonic Circuit (2003)

?

Chip-scale all-optical logic

Why Silicon?

- Silicon is the world's premier material for making nanostructures
- Billions and billions of dollars of infrastructure for making silicon devices

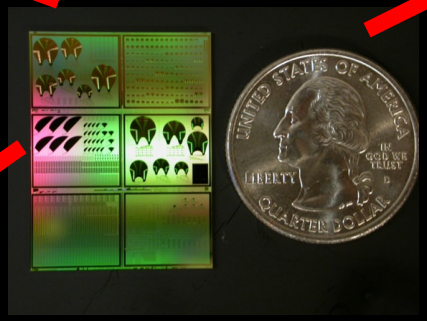
Applications for Silicon Integrated Optics

1,000-10,000 GHz Logic

Radio Frequency Devices

Strong photon-photon interactions

Nano-slot waveguides



Integrate with Electronics

Add Microfluidics

Biosensors

Genalyte

Digital Data Communications

LUXTERA

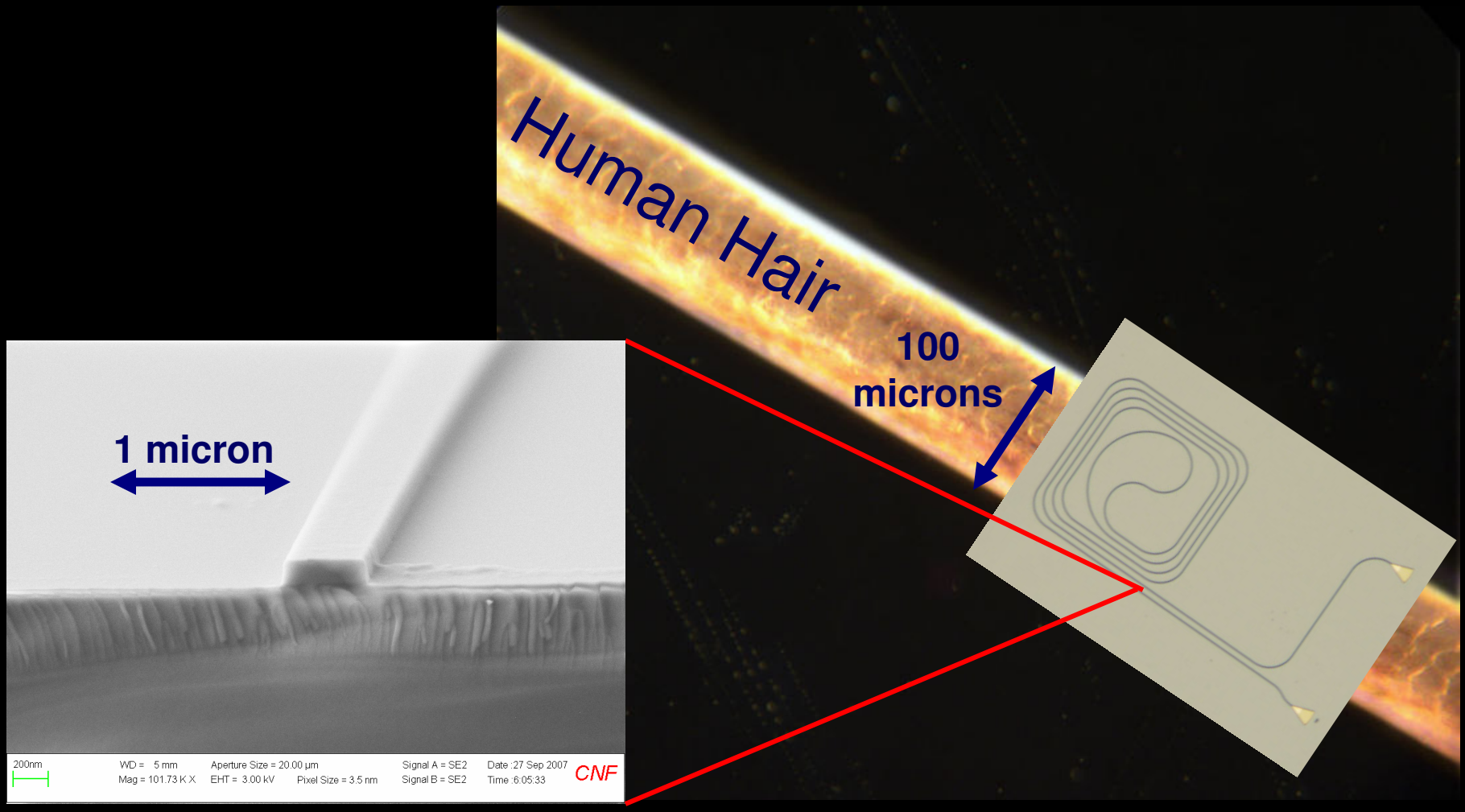
IBM

intel Leap ahead

Nonlinear Mixing

Novel Light Sources

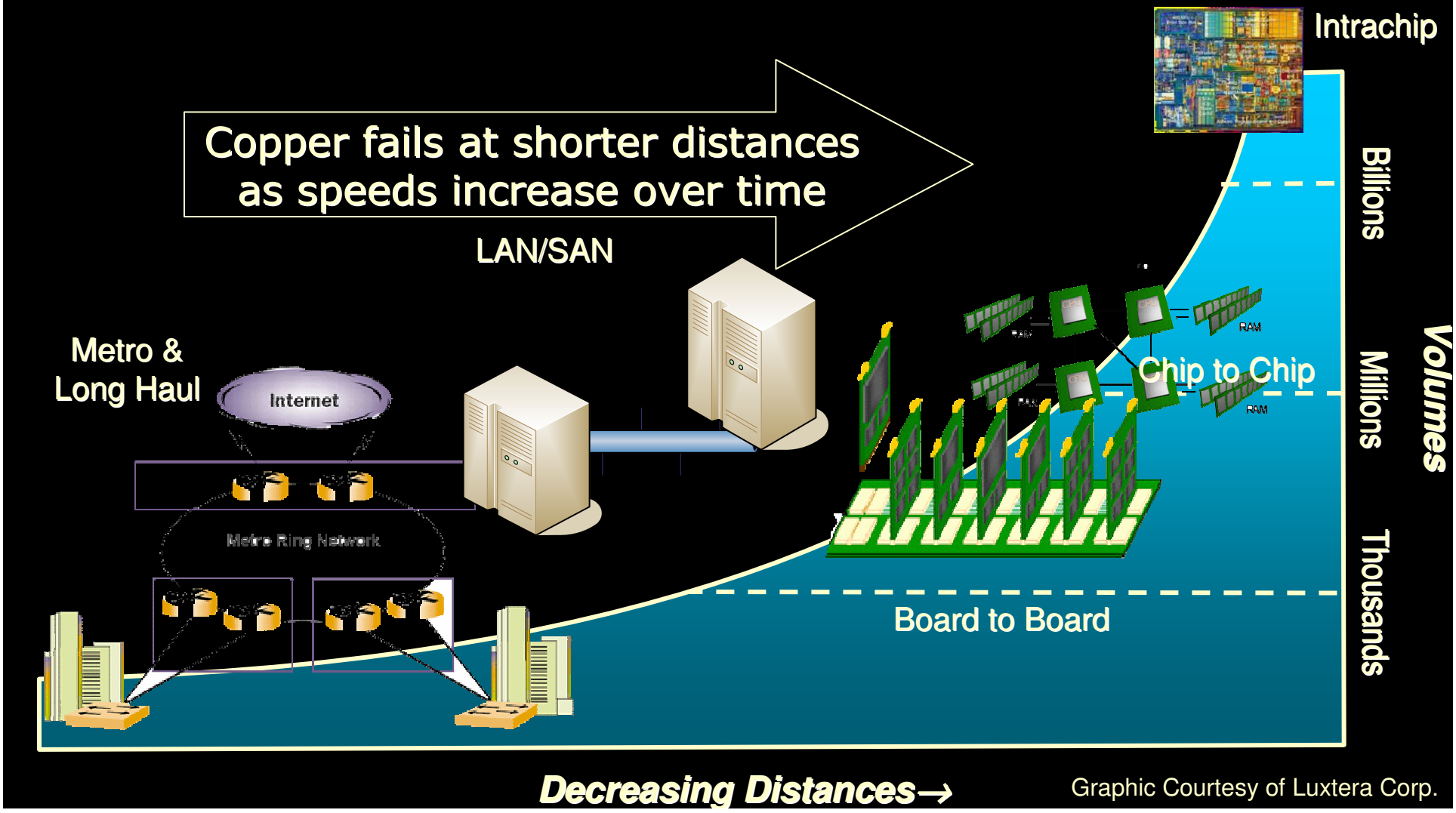
How small are these things?



CMOS Photonics

"In ten years optics will come on every desktop chipset".

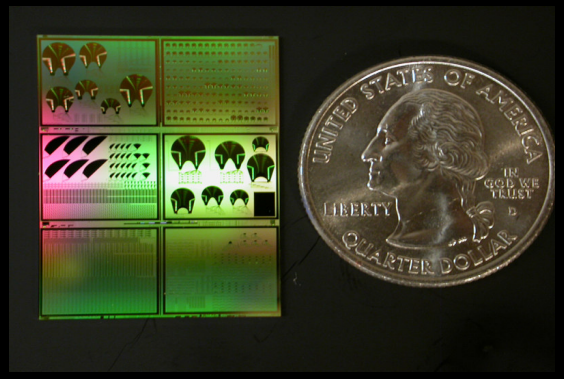
- Intel Communications Group VP Eric Mentzer 4/22/02

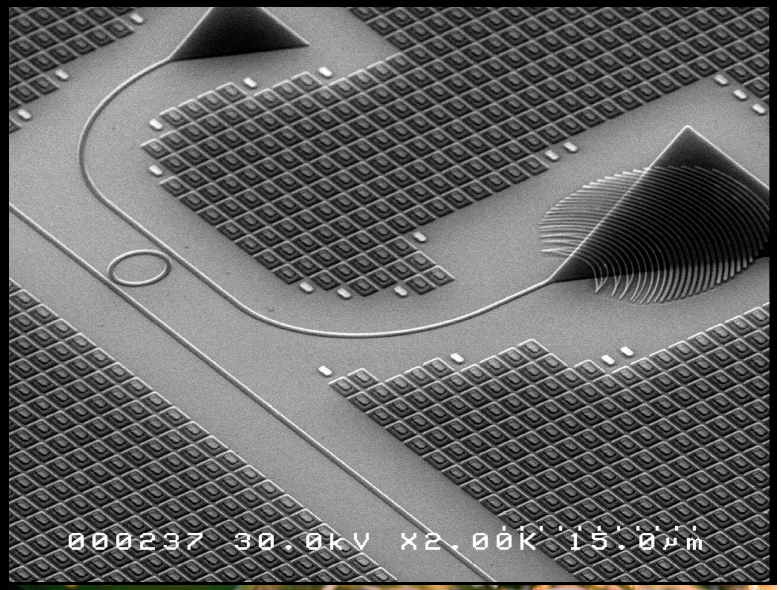


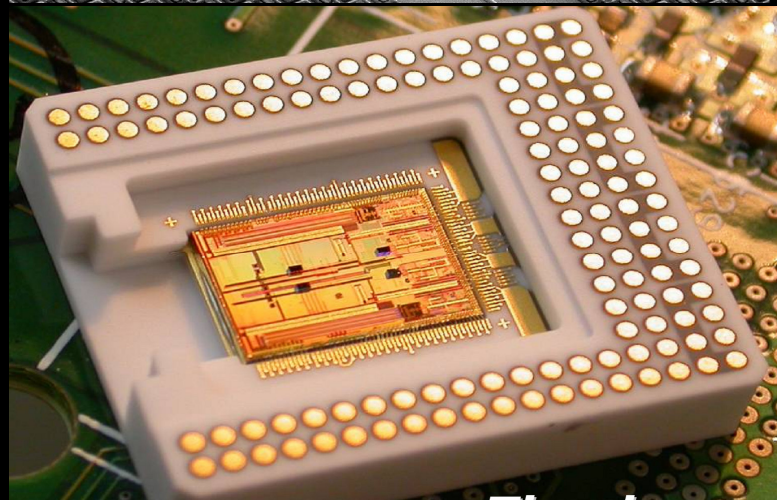
Graphic Courtesy of Luxtera Corp.

Free-carrier Modulators

- Luxtera is commercializing silicon photonics
- 40Gbit/second E-O-E fiber cables for the data center

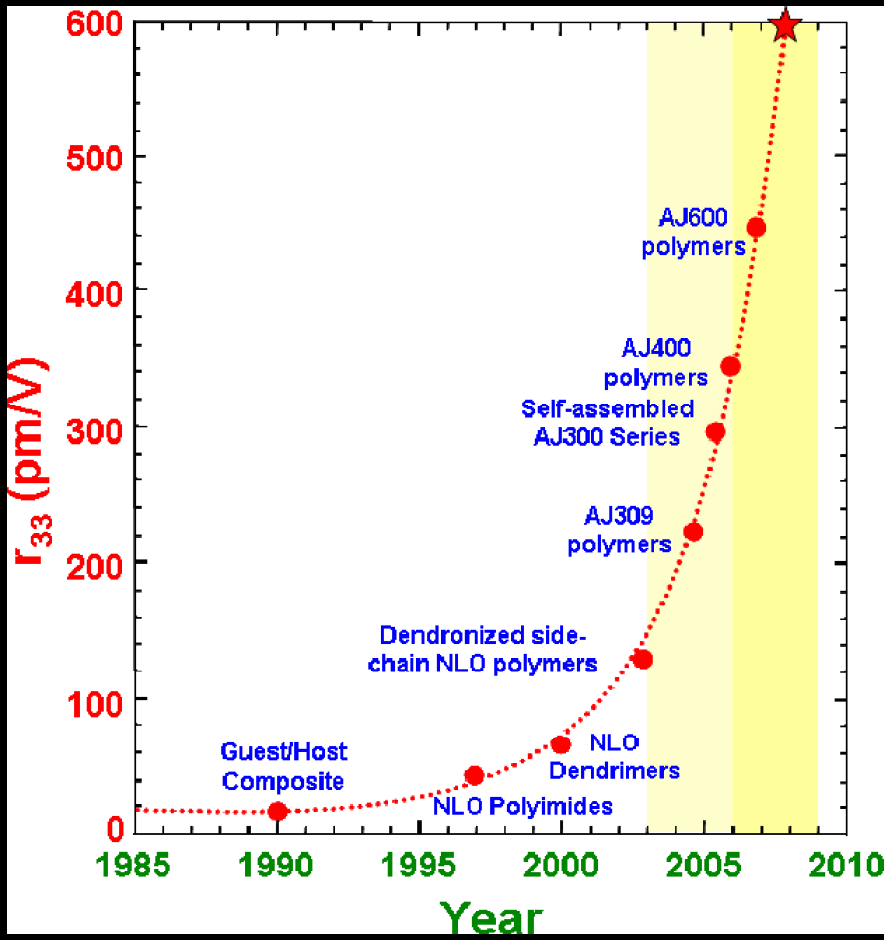






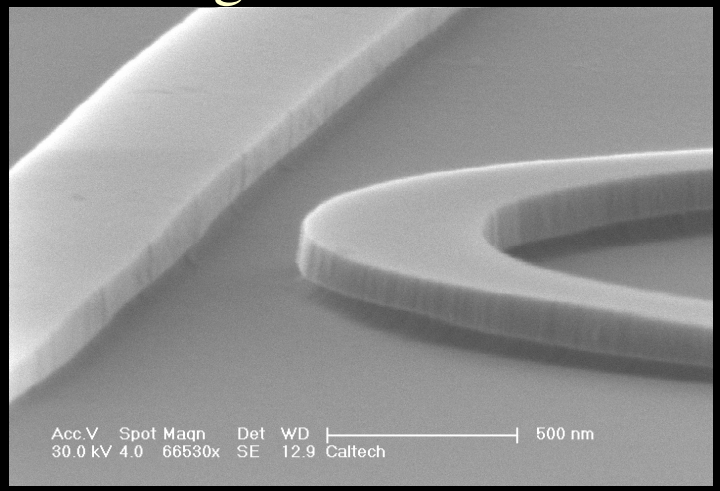
Silicon-Polymer Photonics

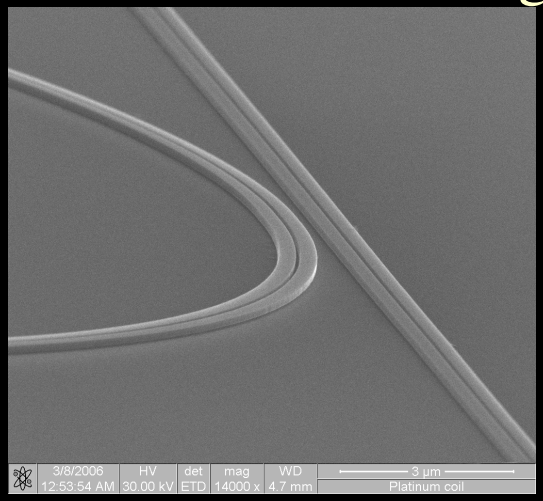
- Organic molecules can be designed and synthesized that have the highest optical nonlinearity known to man.
- Silicon waveguides provide extraordinarily high mode field confinement
- Taken together, these two observations create an opportunity to make light interact with light in unprecedented ways.

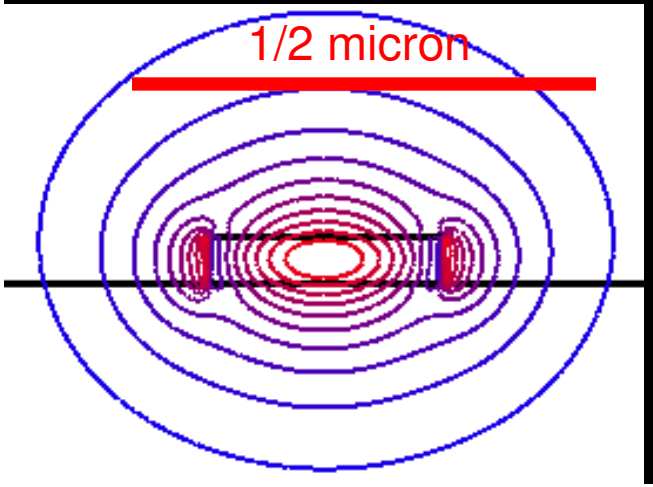


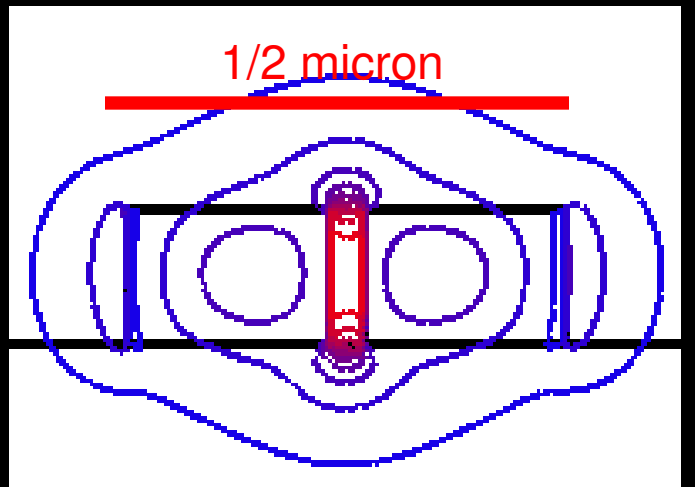
But wait, there's more…

- We can gain an additional improvement – slot waveguides

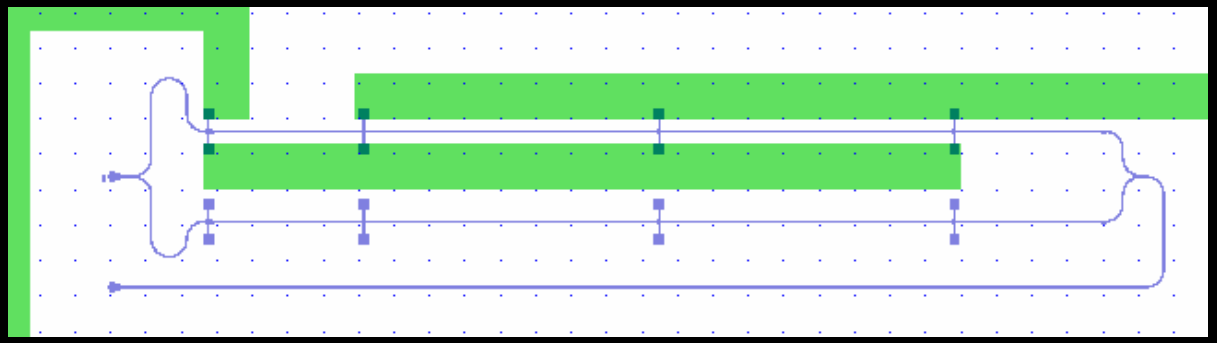


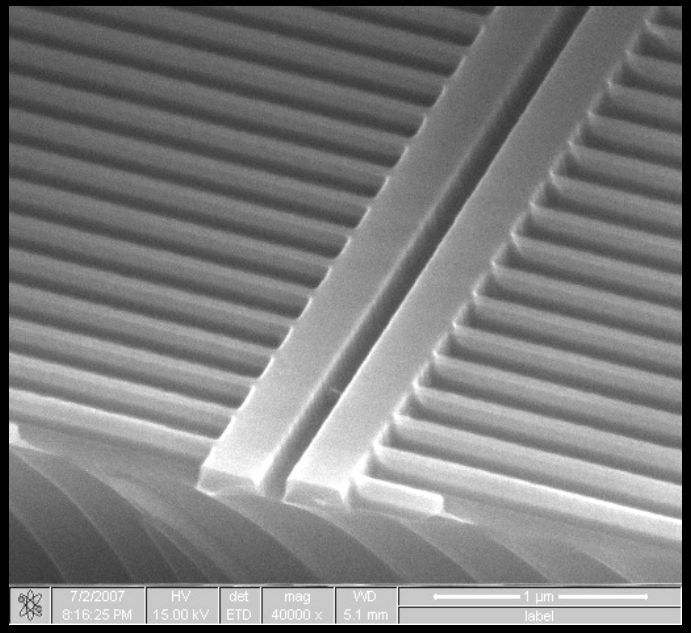




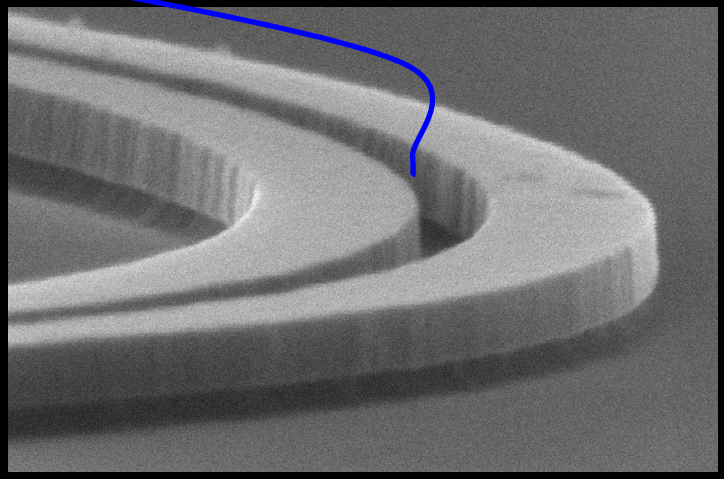


Slot Waveguide EO Modulators



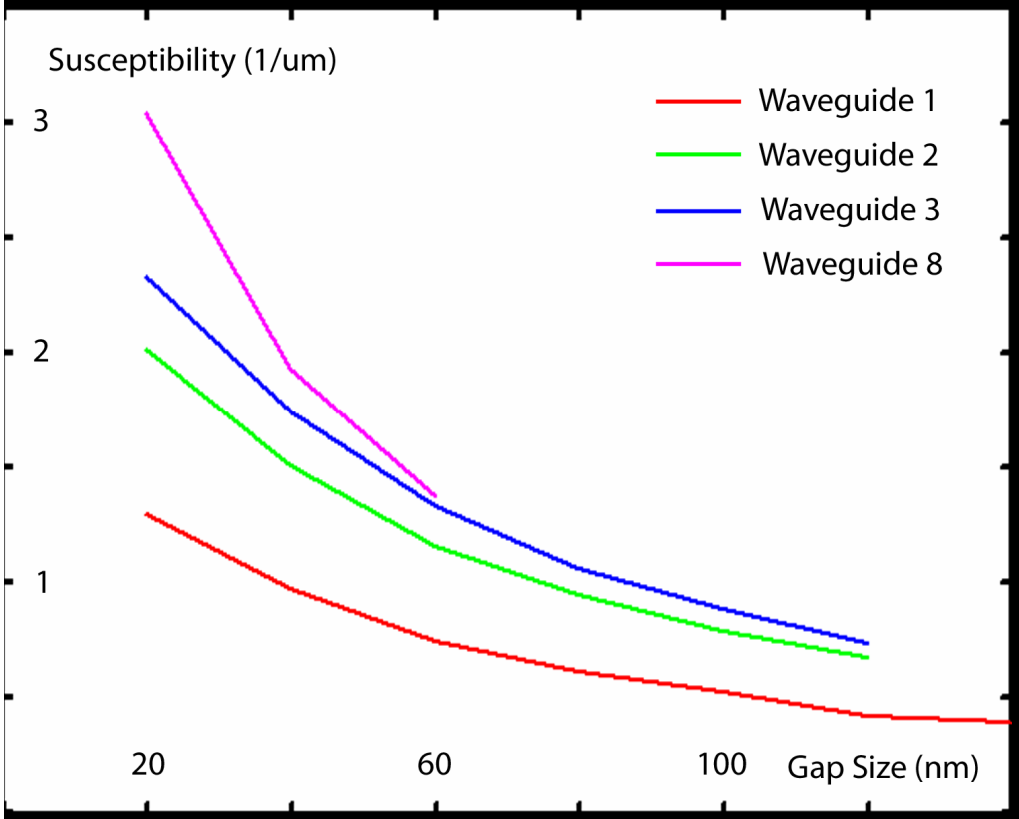


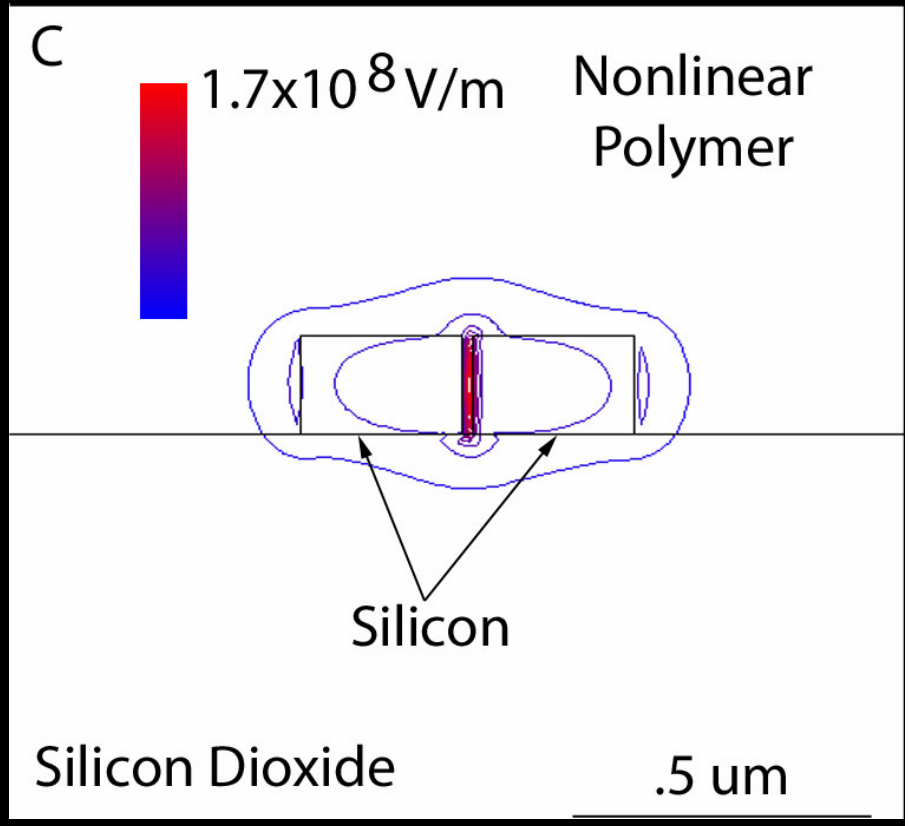
140 nm slot



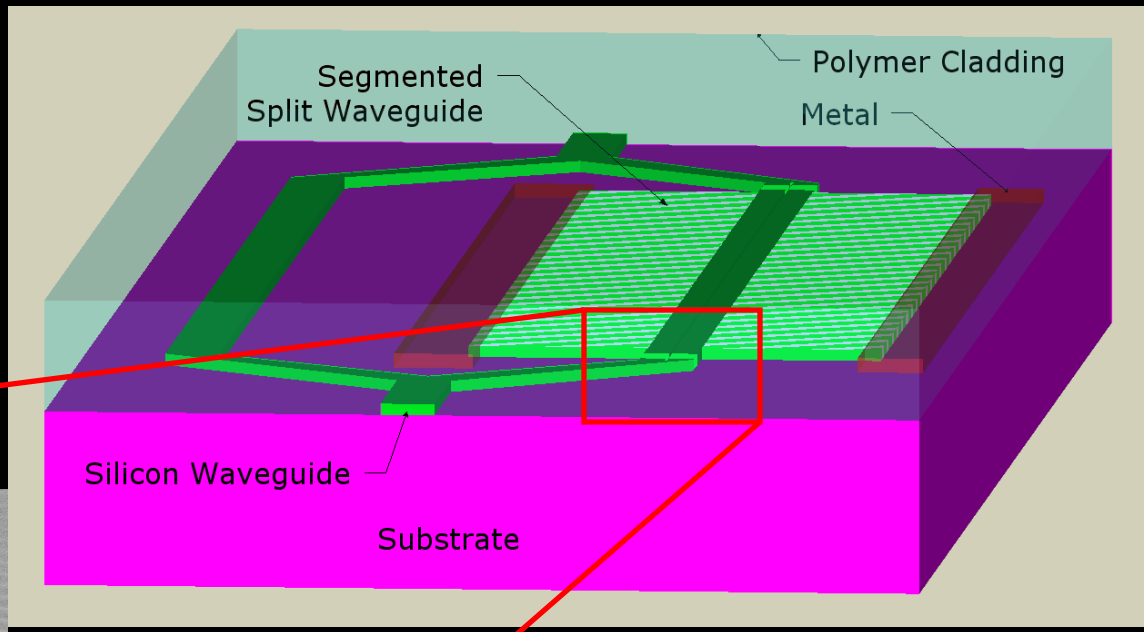
Feb. 21, 2005 **"High-Q Resonators in Silicon-on-Insulator-Based Slot Waveguides," T. Baehr-Jones, M. Hochberg, C. Walker, A. Scherer, Applied Physics Letters, 86 (8):**

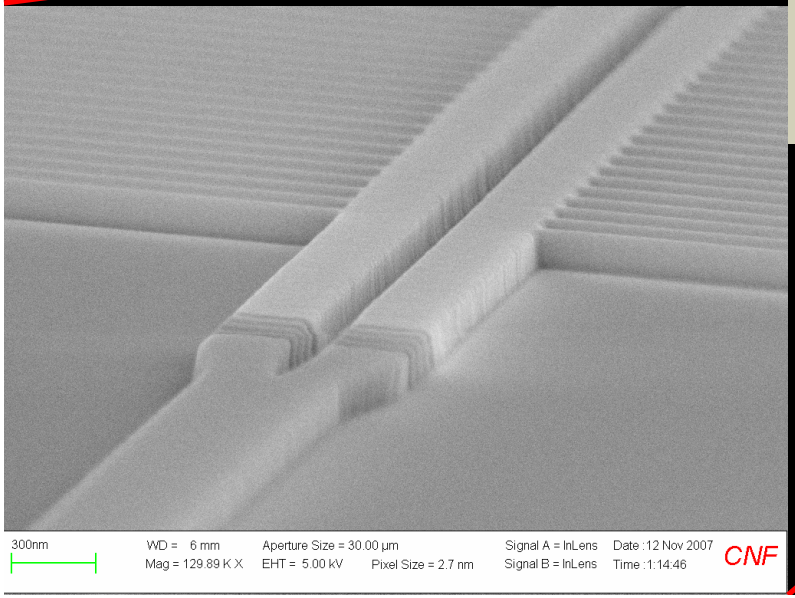
Lithographic Scaling





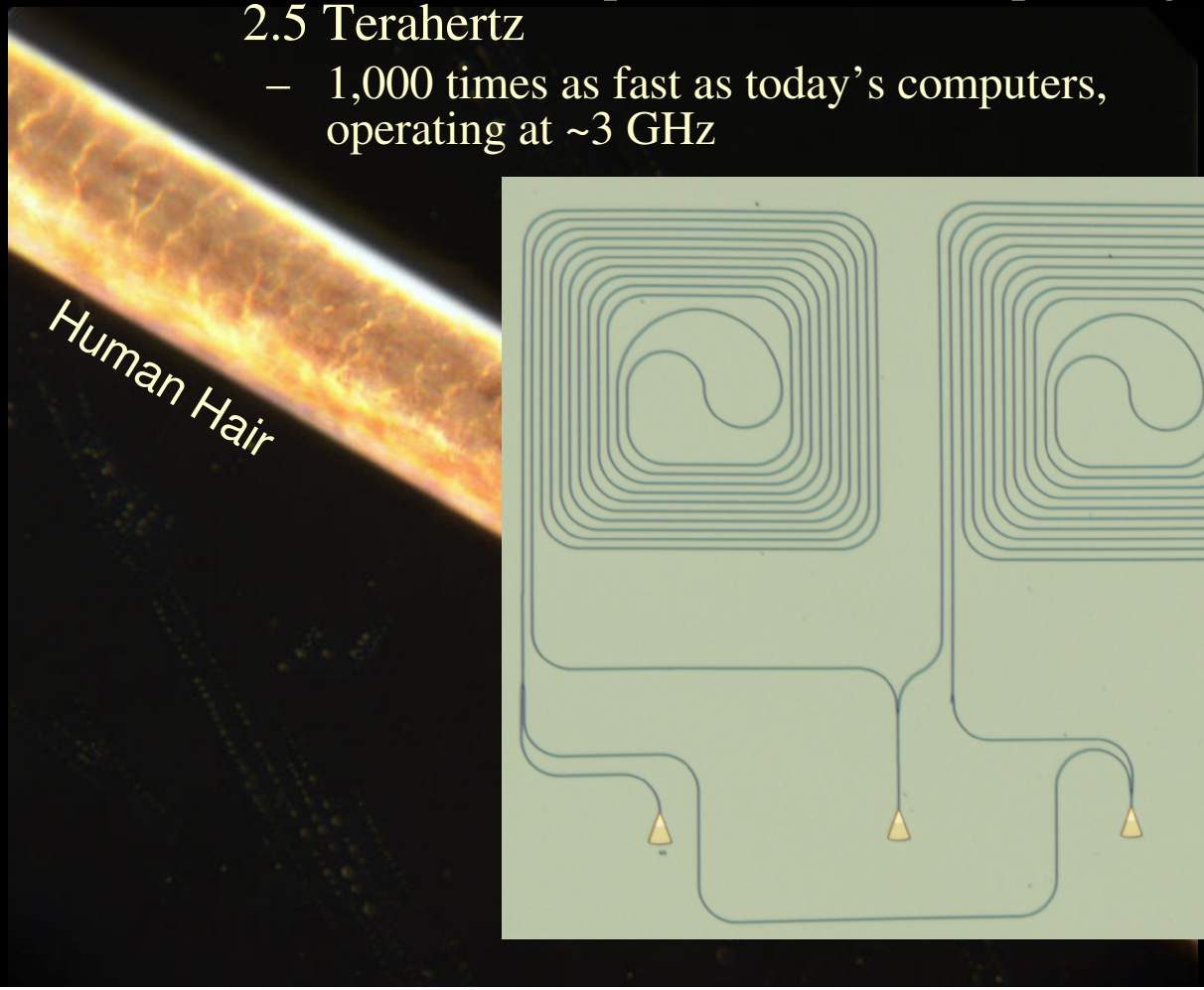
0.25 V Electro-optic Modulators

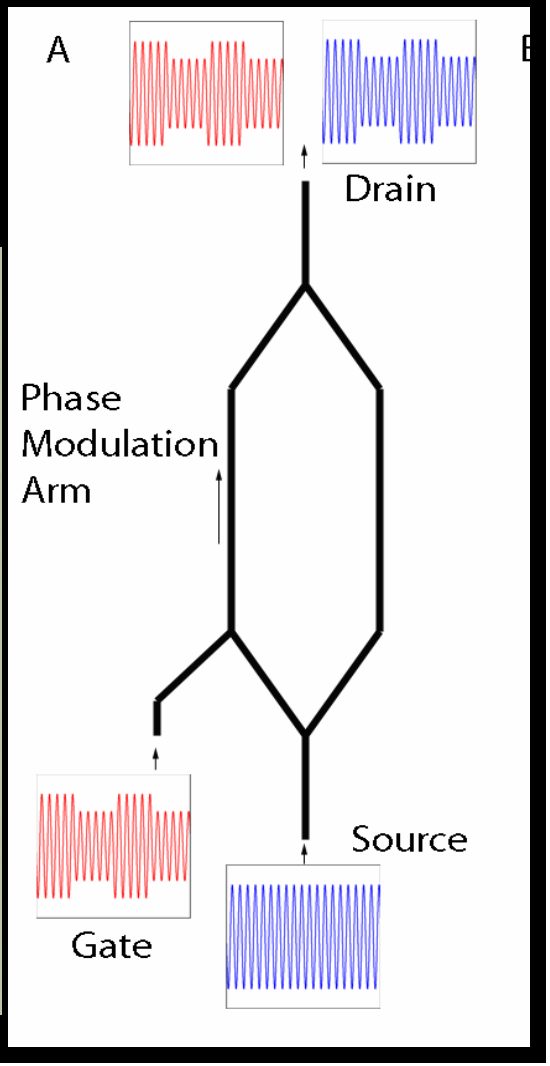




What would an optical transistor look like?

- We've built all-optical modulators operating at 2.5 Terahertz
  - 1,000 times as fast as today's computers, operating at ~3 GHz





Conclusions

- We are on the cusp of being able to do true all-optical logic with bandwidth >1,000 times that of today's electronic circuits
- There are huge opportunities for making unique devices for applications in:
  - Biosensing
  - Aerospace and defense
  - Digital and analog data communications
  - Revolutionizing computer architecture